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AUTHOR Schmitt, Dorren R.
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ABSTRACT

This paper reviews empirical studies of the efficacy of the use of computer assisted instruction (CAI) in various settings, with particular attention to the use of CAI to teach mathematics skills and concepts. Studies using students at various ages and various subjects are considered, as are applications in which CAI was used as the primary instructional vehicle as against studies in which CAI was used as a supplement to conventional instructional intervention. These studies are used to discuss design flaws in CAI research studies, and recommendations are made for improving CAI study designs. It is noted that, in general, CAI has been found to be at least as effective as conventional instructional methods, but superiority of CAI has been demonstrated in only a limited number of studies. Failure to find statistically or educationally significant results favoring CAI may, in some cases, be an artifact of small sample size or other design flaws. CAI appears to be most useful when software includes diagnostic branching that attempts to detect the conceptual difficulties that students experience when confronting certain problems, and then presents instructional activities that focus on individual student needs. (47 references) (Author/GL)

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Title:

Can CAI be more Effective for Teaching Johnny than Traditional Instruction - Why have Studies been Inconclusive?

Author:

Dorren Rafael Schmitt

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ABSTRACT

Computer-assisted instruction (CAI) first became a major area of interest during the 1960s, partially because equipment and software costs had moderated by that time, and partially because federal funds became available to support some of these applications in certain settings. Interest in CAI has continued to escalate as microcomputers have become more available and as more software for these applications has also been developed.

With the advent of microcomputers (such as Apple II, IBM PC, TRS-80, and Commodore PET) research in K-12 and colleges greatly increased since 1975. These studies were designed to determine the general effectiveness of CAI to the best method of textbook or other specific characteristics of CAI. These studies were conducted in three main settings: computer laboratories, remedial instruction, and non-remedial instruction.

This paper reviews empirical studies of the efficacy of CAI use in various settings, with particular attention to the use of CAI to teach mathematics skills and concepts. Studies using various ages of students and subjects are considered, and are applications in which CAI was used as the primary instructional vehicle as against studies in which CAI was used as a supplement to conventional instructional intervention. These studies are used to discuss design flaws in CAI research studies. Recommendations are suggested for improving CAI study designs. Alleviating the design flaws might actually show differences in achievement not yet seen but in a few studies.

In general, CAI has been found to be at least as effective as conventional instructional methods, but superiority of CAI has been demonstrated in only a limited number of studies. Failure to find statistically or educationally significant results favoring CAI may, in some cases, be an artifact of small sample size or other design flaws. CAI appears to be most useful when software includes diagnostic branching that attempts to detect the conceptual difficulties that students experience when confronting certain problems, and then presents instructional activities that focus on individual student needs.

Can CAI be more Effective for Teaching Jonny than Traditional Instruction - Why have Studies been Inconclusive?

The 1960s was the initial introduction of computers into education. Pioneered by IBM and Philco-Ford, computer-assisted instruction (CAI) was developed and brought computers closer to being in the classroom. In the late 1970s, inexpensive computers, such as the Apple II, TRS-80 model I, and Commodore PET, were available for K-12 schools. This began a trend toward deveolping vast numbers of CAI programs and CAI research.

As software has developed, a reorganization of thinking of what a computer can do has emerged. Gellespie (1981) discussed the computer being considered a "tutor" that could provide endless practice, present alternative paths, provide self-pacing, and ask many questions in a variety of formats. The computer also has other advantages, such as presenting the same material to many students simultaneously while serving the needs of the individuals.

Since about 1962, researchers have explored the effectiveness of educational software in the schools under various conditions. Zinn (1965), Wold and Hunter (1984), and James (1986) have argued that CAI is effective for instructing students. But, many studies that these authors reviewed to draw their conclusions had design flaws. In addition, meta-analyses have been performed which contend that CAI is at least not harmful and probably effective (Burns & Bozman, 1981; Hartley, 1978; Hasselbring, 1986; Kulik, Bangert, & Williams, 1983).

Computers have become part of the school environment. This is evidenced by the tripling of the number of computers used for instructional purposes in K-12 schools during the first half of the 1980s. In light of the expanding availability of computers, several questions have arisen. First, is CAI a viable method to effectively instruct independently of other instruction? And secondly, why have previous studies been inconclusive about the effectiveness of CAI?

Viability of CAI to Instruct

In the past few years, there have been many educators arguing that CAI is effective for instructing students (James, 1986; Wold & Hunter, 1984; Zinn, 1965). These authors describe

the types of instructional programs, the development of the software, and even how to use the software. What is lacking is information describing the successful implementation of the software with student achievement improved. Most articles relate to the viability of CAI as a supplement to classroom instruction or independent of classroom instruction. But the fundamental question is can CAI aid student learning? The follow-up questions include: whether some program are effective and othere are not; and how should CAI and computers be used within the curriculum?

Computer Laboratories

Several studies have explored the effect of computer labs in which students "experiment with concepts or applications or explore repeated applications of course content" (Sterrett and Karian (1978, p. 114). Sterrett and Karian (1978) used a statistical laboratory in an introductory non-calculus statistics course. The 35 students in two statistics classes were given accounts and data sets to explore the concept of statistical significance. Sterrett and Karian (1978) found that the use of this lab "enhanced the students' ability to understand the nature of experimental results and statistical reasioning" (p. 1116). But, statistically significant nor educationally significant results were found.

Lang (1973) employed CAI as a supplement to introductory calculus course instruction. The CAI supplemented the class work of 19 students, with additional homework assignments intended to reinforce several topics taught in class. The 15 non-CAI students received similar homework assignments concerning the same topics, but without the use of the computer. Lang (1973) found that concept attainment was enhanced with the use of CAI. Lang (1973, p. 5662A) concluded that CAI has the potential to be "an effective means of improving the students' understanding of the basic concepts of calculus". No statistical significance was found for achievement even though that broad conclusion was made.

In 1975, Calswell and Polley created a computer lab which presented students with practice problems with randomly generated problem parameters. The students solved the problemss and entered the solution into the computer. The computer would diagnose the solution, if it was incorrect, and match an error to the answer. Caldwell and Polley (1975) found that this diagnosis was helpful to some students, but did not eliminate the need for other types of instructional aids.

These three studies illustrate that computer can, with at least moderate success, supplement traditional instruction. But, from these studies, computers seem an improbable solution for eliminating the need for teachers or for other instructional aids.

Remedial Instruction

CAI has also been employed for remedial instruction. CAI has been used both as a supplement to traditional instruction as well as the sole means of instruction for remediation. During the 1970s, many educators felt this was the dominant role that CAI should take.

Sherman (1975) conducted a project evaluating the use of CAI to remediate the multiplication and division skills of college students. Sherman selected all students scoring zero percent on a diagnostic test. The 35 experimental group students received CAI while the 82 control group students received "traditional" lecture on the same material. Sherman (1975) found that CAI successfully facilitated student achievement on all insstructional objectives.

In 1984, Glidden, Harrald, Hodges, and Kunec supported the conclusion made by Sherman with Coast Guard entrants. These researchers reported statistically significant treatment effects as measured by the Armed Forces Vocations Aptitude Battery.

Imboden (1985) studied the effects of computer enhanced instruction on low achieving college students learning the concept of percent. Thirty-eight subjects in the freshment through junior year were assigned to either the experimental group, computer enhanced instruction, or the control group, lecture method, with both groups covering the material to essentially the same degree. Imboden (1985) found that the computer enhanced instruction appeared not to be different from the lecture method.

These studies highlight that CAI is a viable means of presenting material for remedial instruction. All of the studies discussed used the CAI for sole instruction but also had a narrow focus. No studies were found that used CAI for remediation and used it as a supplement to "traditional" instruction. This indicates a gap in the research.

Non-Remedial Instruction

The use of CAI as a means of non-remedial instruction has been the foucs of various studies involving students from elementary to post graduate educational levels. Research ranges from the investigation of using CAI to teach specific topics to using CAI to teach the entire course. Two recent studies illustrate the use of CAI to teach an entire course.

Enochs, Handley, and Wollenberg (1986) used a stratified random sample dividing 50 U.s. Navey Yoeman "A" students into two groups: "those taught traditionally in self-paced mode and those taught via CAI" (p. 136). Enochs et al. (1986) found that there were statistically significant differences in achievement gains across groups which favored the CAI group.

Ozarowski (1973) investigated the use of CAI in college statistics classes. Ozarowski (1973) assigned 23 subjects to each group, experimental and control, by matching. The students covered the same material normally undertaken in a basic statistics course. The researcher found that the time taken to complete the course was statistically significant less when the computer method was used rather than the conventional classroom method of instruction. Learning gains were also statistically significant in favor of the students being instructed by the computer (Ozarowski, 1973). These results are even more noteworthy given the relatively small sample size.

The studies by Encohs et al. (1986), Imboden (1985), and Ozarwski (1973) indicate that CAI is at least as effective as "traditional" instruction when CAI is used to teach an entire course. There is also evidence that CAI is better than "traditional" instruction in the length of time students need to learn material and the achievement level.

As a note, there are numerous CAI studies conduct with one to five topics. Thse studies show nominal achievement gains in favor of CAI, but never statistically significant differences. The lack of statistical significance are due to the small sample sizes, but even a greater problem is the shortness of the study. Thus, there may be more effectiveness in CAI than these studies can ever determine because of design flaws.

Design Flaws in CAI Studies

Reviews of educational software effectiveness (Chambers & Sprecher, 1980; Colorado, 1988; Schmitt, 1987; Schmitt, 1989) studies have noted four major research design weaknesses: small sample sizes, lack of identified criteria for determining "quality" software, inappropriately used statistics, and inadequate time allocated to conducting the study. Because the actual studies have design flaws, these research design weaknesses will be reflected in the results of the studies and even compounded should meta-analyses, using these studies, be performed since meta-analyses are analyses of an analysis of data.

This section discusses these four major weaknesses in many CAI studies. Sixteen studies are used to illustrate the design weaknesses frequently found in CAI research but is also common in other educational research endevors.

Selection of Research Studies

Several sourses of educational papers were surveyed, ERIC, Dissertation Abstracts Internation, and educational journal, from 1970 through 1987. Sixteen CAI studies in mathematics published during this 17 year period were randomly selected to be used to illustrate the research design weaknesses in CAI studies.

The appenidx has a table lists the various characteristics of CAI studies in mathematics. This table present the sample size, the length of the study, the software used (commercial, public-domain, self-made, or unknown), the statistical procedures employed, and the conclusions (more effective, no difference, less effective) with traditional instruction.

Small Sample Sizes

One controlable research design aspect is the sample size. The second level questions the researcher asks are:

Who is my population?
Who will be in my sample?
And, how many people will be in my sample?

These three questions usually follow the definition of the research problem and development of the research questions. Tables and/or formulas can be found in any number of social science statistics books to determine the sample size required to have sufficient "power" for the study.

CAI researchers like many other educational researchers neglect sample size. The mean sample size in these 16 CAI studies reviewed was 74. This is the sample size for the entire study, not just a level of a way. Difficulty achieving statistical significance is suprising due to this fact. Most CAI studies do not have sufficient "power". Not only are these studies not statistically different, but if educational significance is explored, through effect sizes, many of these same studies do not indicate educational significance in the findings. This is also supported by conclusions by (Colorado, 1988; Schmitt, 1987).

As examples of small sample sizes, Pachter (1979) used a sample of 29. Other studies using a sample size in the thirties were Sterrett and Karian (1978), Lang (1973), Robichaud (1986), Imboden (1986), and Wilson (1986) with samples between 29 and 38. Three studies did have large samples: Goodson (1975) with 93, Sherman (1975) with 117, and Shapiro (1977) with 400 subjects.

There are solutions to this problem. Instead of using a single school and one grade level, the researcher could use two schools. One school could be the control group and the other could be the experimental group. If more than two groups are needed expand the number of schools. This would increase the sample two fold or by the number of research groups needed for the study.

A second solution would to take multiple schools and have all of the research groups microcosums of the research study. Instead of having three schools, each school representing a different group, have each school have the three groups thus amounting to a similar sample size as the above suggestion.

A final suggestion would have several researchers from different school districts or states work on the same study. Each researcher would have all the groups in his "sub-study". This would not only increase the sample size but also the generalizability of the study.

These soultions are just three logically thoughout solutions to the problem of sample size. This author feels that one of the major reasons statistical and/or educational significance has not been found is due to sample size. The lack of greater effectiveness over traditional instruction has hindered the expanded use of CAI in some form of classroom instruction. The findings of these past studies has also hindered the further investigation of CAI effectiveness similar to the past and in other aspects.

Duration of the Study

The duration of the study is usually largely under the control of the researcher. Although, the availability of students and the liberties schools and teachers give researchers may be constraining, the researcher does have a reasonable amount of control over how long the study will take place.

The second design flaw found in many CAI research studies is the length of the study. Several of the studies (i.e., Imboden, 1986; Shine, 1983; Pachter, 1979; Goodson, 1975) only lasted through one topic. In science and mathematics, a topic may last one to three days. This limits the study to the length of time the single topic is discussed. Other studies lasted through multiple topics. Finally, there were some studies that lasted a semester or longer: Sterrett and Karian (1978), Lang (1973), Crenshaw (1983), and Ozarowski (1973).

The length of time is largely determined by the number of software packages are used in the study. On one dimension there are the topics that will be included in the study (i.e., solving linear equations, long vowels, the solar system). On another dimension, usually neglected, is the variety software package types that can be used (i.e., drill and practice, tutorial, simulation and demonstration, games). The studies report the topics and usually only employ one type of software package. A more accurate deption of how effective CAI is on a given topic might be to use several differnt software types on the same students or on different student and observe differences.

Even those studies which lasted a semester, the students may have only had limited use of the computers. Use once a week or every other week could possibly not show differences as much as using the computers twice or three times a week throughout the semester.

This is not to say that the general duration, a semester or even multiple topics is not long enouth, but this author is suggesting that actual computer usage would be a better indicator. CAI studies have varied from students using the computer 15 minutes per session to one hour per session. The duration of the sessions makes a dramatic difference when discussing ten 15 minute sessions compared to ten one hour sessions.

Additionally, if the sessions are distributed over various topics and multiple software types are used, there is more likely to be statistical and/or educational significance. The length of the study most definitionally has an effect on either measure of significance. And obviously, the results will also be more stable over time and over software types. This may also produce more generalizable results.

Software Quality

The lack of knowledge of the software quality or the lack of quality software used is considered an inexcusable design flaw. Educational software quality ranges from abonable to excellent (Allen, 1984; Bitter, 1984; Burke, 1982; Jensen, 1985; Kamil, 1984; Komoski, 1987; Lathrop & Goodson, 1983; Staples, 1985; Taylor & Ely, 1987). Staples (1985) has stated that there is a tremendous amount of variation in the quality of software, but the largest quantity is the poorer software. With the amount of poor quality software, the "educational merits of [software] packages need to be questioned" (Niman, 1987, p. 57).

All of the studies reviewed either did not state what software was used or defined the software as made by the researcher (self-made). There was no discussion in any study pretaining to the quality of the software. This is disturbing since one major criticisms of CAI by teachers is that "there is no good software out there" (Balajthy, 1988, p. 51).

The quality of the software is the backbone of all CAI studies. If the software is not excellent or at least good, then CAI may be found to be ineffective or at least as effective as "traditional" instruction. The quality or lack there of in the research software is compounded by the previous two flaws, particularly the duration of the study.

The major concern for this author is not so much that the researchers developed the software for the study, but that the quality of the software was not documented. This is particularly a concern in those papers from ERIC since there is no page limitations.

Suggestions for documenting the quality of software whether it may be commercial, public-domain, or self-made. First, if the software being used in the study was commercially produced, check in ERIC or subject matter journals for reviews of the software (i.e., MicroSIFT, Alberta, Arithmetic Teacher, Mathematics Teacher, English Teacher, Reading Teacher, Science

Teacher). Second, if the software was not commercially produced, locate a software evaluation instrument (i.e., MicroSIFT, NCTM, NCTE, or other published in ERIC or various journals). Third, provide documentation from referencing the review found or a summary of the software evaluation. Finally, discuss reason for using particular software particularly if the software was self-made and/or received a poor review or evaluation.

It is this authors opinnion that the major downfall of past CAI research studies has been the lack of quality software. This has placed both CAI research and the use of CAI software in jepordy. Without credible software research studies will fail to accurately determine efffectiveness or ineffectiveness of CAI.

Statistical Procedures Employed

To this point, most studies have relied on univariate statistics. The predominant statistical procedures employed have been analysis of variance (ANOVA) and t-tests. In and of themselves there is nothing wrong with these statistical procedures, but they have been misused and overused.

The three statistics that were used by all of the reviewed studies were ANOVA, t-test, and regression. Given the data, the general type of statistics used was appropriate. One problem is that in several studies, multiple ANOVAs and multiple t-tests were employed. This is problematic.

The same logic used by textbooks supporting the use of ANOVA tests over t-tests can be made for using multivariate statistics over multiple ANOVAs. If the alpha is set at .01, with one ANOVA there is a 5 percent chance that the test would be declared statistically significant (Asher, 1976). This is termed experimentwise Type I error.

When more than one ANOVA, or any other univariate test, is performed on the same dependent variables the experimentwise Type I error probability is increased exponentially. This error can range from the set alpha level, when all of the dependent variables are perfectly correlated, to "1 - (1 - alpha) raised to the k power, where k is the number of statistical test conducted" (Thompson, 1986, p. 6), when all of the dependent variables are perfectly uncorrelated. The most troubling fact is that except at the two extremes, the actual experimentwise error rate cannot be readily determined (Thompson, 1986). The result is a greater probability of

statistical significance (McMillan & Schumacher, 1984; Sowell & Casey, 1982). Thus, instead of multiple univariate statistics, one multivariate statistic should be employed.

But beyond the fact that the probability of statistical significance is greater, multivariate statistics also better represent the reality of the classroom. And, the classroom is where the CAI will be used. Thompson (1986) argues that the statistical procedures should be as complicated as the environment in with the data was collected. The classroom is not simple. And, there is not one dependent variable that is involved. Achievement, interest, and attitude are just three aspect that are involved in all learing, whether or not the computer is used. These three aspects, and possibly others, need to be assess together and not independently. Additionally, differet aspects of achievement should not be investigated independently, but together as well.

CAI research, like much of educational research, has neglected the need and usefulness of multivariate statistics. Univariate statstics can be used. And there are appropriate situations. But, when multiple univariate tests need to be employed, multivariate tests are then most appropriate.

Finally, educational significance or effect sizes has been neglected throughout CAI research. An effect size, often R^2, is used to determine educational significance. One of the easiest effect sizes to calculate is (sum of square explained divided by sum of squares total) . Even is there is no statistical significance, especially with a small sample size, there may be educational difference. And obviously, the higher the percentage of difference the greater the difference.

Design Flaws Affecting Meta-Analyses

Simply put, meta-analysis is the "analysis of analyses" (Glass, 1976, p. 3). Basically, meta-analysis is the reviewing of a collection of studies to summarize statistics (Kulik & Kulik, 1988). Kulik and Kulik (1988) explain that meta-analysis is not based on statistical significance by effect sizes and the strength of relationships.

Because meta-analyses rely on other studies, the meta-analysis study incorporates any problems the reviewed studies might have. Thus, CAI meta-analyses also incorporate the flaws described above. Most specifically, length of the study and the quality of the software. Due to the use of effect sizes, the sample size does not influence the meta-analysis as much

as if statistical significance was investigated, since statistical significance is largely a product of sample size.

The flaws of the studies do influence the results of meta-analyses. This compounds the problems since many educators rely on the meta-analyses as the literature for the effectiveness of CAI because of the vast numbers of CAI studies. The meta-analyses can provide a false sense of success with CAI that has not been shown to necessarily be present in CAI studies.

Summary

There are design flaws with past CAI effectiveness studies. After reading a few studies this conclusion seems obvious. But, all is not lost. If researchers heed the recommendations for improving CAI studies there may be some hope.

As the technology of computers grows and the demand for computers in schools from within the education profession and from parents increases, there needs to be accountability that CAI is useful, effective, and necessary. Unless there are sound research studies to backup the use of CAI, it will fall like a dead duck.

CAI may not be effective as the sole means of instruction, but that does not mean it is not useful and necessary, the jury is still out. But, CAI does seem viable for remediation and long self directed courses. The CAI researchers need to provide the fuel to spark the demand for quality CAI and appropriate uses of the software.

REFERENCES

Allen, M. W. (1984). Educational computing software: State of the art in 1984. Educational Technology, 24, (10), 7-10.

Asher, J. W. (1976). Educational research and evaluation methods. Boston: Little, Brown.

Balajthy, E. (1988). Computers and instruction: Implications of the rising tide of criticism for reading education. Reading Research and Instruction, 28, 49-59.

Barnes, K. (1984). Selecting 'good' stuff in computer training in a 2-sided job. PC Week, 1(10), 23.

Bitter, G. G. (1984). Hardware and software selection and evaluation. Computers in the Schools, 1(1), 13-28.

Burke, R. L. (1982). CAI sourcebook. Englewood Cliffs, N.J.: Prentice-Hall.

Burns, P. K., & Bozeman, W. C. (1981). Computer-assisted instruction and mathematics achievement: Is there a relationship? Educational Technology, 21(10), 32-39.

Caldwell, J. L., & Polley, D. (1975). Computer-assisted tutorials in college mathematics. American Mathematical Monthly, 82, 846-848.

Chambers, J. A., & Sprecher, J. W. (1980). Computer-assisted-instruction: Current trends and critical issues. Communication of the ACM, 23, 332-342.

Colorado, R. J. (1988). Computer-assisted instruction research: A critical assessment. Journal of Research on Computing in Education, 20, 226-233.

Crenshaw, H. M. (1983). A comparison of two computer assisted instruction management systems in remedial mathematics. Dissertation Abstracts International, 43, 3467A. (University Microfilms No. 83-06,839).

Enochs, J. R., Handley, H. M., & Wollenberg, J. P. (1986). Relating learning style, reading vocabulary, reading comprehension, and aptitude for learning achievement in the self-paced and computer-assisted instruction modes. The Journal of Experimental Education, 54, 135-139.

Glass, G. V. (1976). Primary, secondary, and meta-analysis of research. Educational Researcher, 5, 3-8.

Glidden, W. c., Harrald, J. R., Hodges, R. A., & Kunec, J. (1984). The Coast Guard's CAI approach to basic math and reading skills. Paper presented at the National Adult Education Conference, Louisville, KY. (ERIC Document Reproduction Service No. ED 249 365).

Goodson, C. E. (1975). A study of the effectiveness of computer assisted instruction as compared to traditional instruction when utilized in technical mathematics for college students in business and engineering technology. Dissertation Abstracts International, 36, 2688A-2689A.

(University Microfilm No. 75-23,934).

Hartley, S. S. (1978). Meta-analysis of the effects of individually paced instruction in mathematics (Doctoral Dissertation, University of Colorado, 1977). Dissertation Abstracts International, 38, 4003A. (University Microfilms No. 77-29,926).

Hasselbring, T. S. (1986). Research on the effectiveness of computer-based instruction: A review. International Review of Education, 32, 312-324.

Imboden, H. H. (1986). The effects of computer enhanced instruction in teaching concepts of percent to low achieving college students. Dissertation Abstracts International, 46, 3378A. (University Microfilm No. 85-25,768).

James, E. B. (1986). Computer-based teaching for undergraduates: Old problems and new possibilities. Computer Education, 10, 281-292.

Jensen, C. B. (1985). Using what we have learned in the past to improve the future of courseware design. AEDS Journal, 19(1), 28-48.

Kamil, M. L. (1984). Software: Evaluation and decisions. Computers, Reading, and Language Arts, 1(4), 15-16, 26.

Komoski, P. K. (1987). Keynote address: Educational microcomputer software evaluation: Its challenge and its uniqueness. In J. Moonen and T. Plomp (Eds.), Eurit 86 developments in educational software and courseware (pp. 399-404). Oxford: Pergamon Press.

Kulik, J. A., Bangert, R. L. , & Williams, G. W. (1983). Effects of computer-based teaching on secondary school students. Journal of Educational Psychology, 75, 19-26.

Kulik, J. A., & Kulik, C-L. C. (1988). Meta-analysis: Historical origins and comtemporary practices. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Lang, M. T. (1973). Computer extended instruction in introducing calculus. Dissertation Abstracts International, 34, 5662A. (University Microfilm No. 74-5,271).

Lathrop, A., & Goodson, B. (1983). Courseware in the classroom selecting, organizing, and using educational software. Menio Park, CA: Addison-Wesley.

McMillian, J. H., & Schumacher, S. (1984). Research in education: A conceptual approach. Boston: Little, Brown.

Niman, J. (1987). Precollege mathematics software: Limitations and Potential. In J. Moonen and T. Plomp (Eds.), Eurit 86 developments in educational software and courseware (pp. 55-65). Oxford: Pergamon Press.

Ozarowski, P. C. (1973). A study in the design and

implementation of a course in the basic fundamentals of statistics via a computer. Dissertation Abstracts International, 34, 2310A. 9University Microfilm No. 73-27,317).

Pachter, S. (1979). A computer assisted tutorial module for teaching the factoring of second degree polynomials to regent level ninth year mathematic students. Dissertation Abstracts International, 40, 1843A. 9University Microfilm No. 79-23,610).

Robichaud, K. K. (1986). The use of computer assisted instruction with adult basic education students: A comparative study. Dissertation Abstracts International, 47, 1985A. (University Microfilm No. 86-21,681).

Rockhill, T. D. (1971). The development of an individualized instructional program in beginning college mathematics utilizing computer based resource units. Final report. (ERIC Document Reproduction Service No. ED 053 966).

Schmitt, D. R. (1987). The effects of various approaches to using CAI to teach mathematics: A literature review and possible research agenda. Paper presented at the annual meeting of the Mid-South Educational Research Association, Mobile, AL.

Schmitt, D. R. (1989). Methodological weaknesses with CAI research. paper presented at the annual meeting of the Eastern Educational Research Association, Savanah, GA.

Schoen, H. L. (1972). A comparison of four types of feedback to student responses on a CAI unit designed to teach the concept of function. Paper presented at the National Council of Teachers of Mathematics Annual Meeting, Chicago, IL. (ERIC Document Reproduction Service No. ED 061 081).

Shapiro, L. (1977). Tutor resources in mathematics. American Mathematical Monthly, 84, 476-481.

Sherman, J. F. (1975). The development of a computer assisted math review for physical science survey students at Bevard Community College. Ed.D Dissertatio, Nova University. (ERIC Document Reproduction Service No. ED 137 084).

Shine, S. S. (1983). A comparison of programmed instruction versus lecture-demonstration as a method for teaching digital computer arithmetic at the post-secondary school level. Dissertation Abstracts International, 43, 3529A. (University Microfilm No. 83-06, 819).

Sowell, E. J., & Casey, R. J. (1982). Research methods in education. Belmont, CA: Wadsworth.

Staples, B. (1985). Educational computing: Where are we now? Creative Computing, 11(4), 62.

Sterrett, A., & Karian, Z. A. (1978). A laboratory for an elementary statistics course. American Mathematical Monthly, 85, 113-116.

Taylor, R., & Ely, D. P. (1987). Courseware quality: Do development and design procedures make a difference? In J. Moonen and T. Plomp (Eds.), Eurit 86 developments in educational software and courseware (pp. 405-410). Oxford: Pergamon Press.

Thompson, B. (1986). Two reasons why multivariate methods are usually vital: An understandable reminder with concrete examples. Paper presented at the annual meeting of the Mid-South Educational Research Association, Memphis, TN.

Walker, E., & Azumi, J. E. (1985). The impact of computer assisted instruction on mathematics learning gains of elementary and secondary students. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL. (ERIC Document Reproduction Service No. ED 275 487).

Wilson, S. A. (1986). The construction of computer-assisted instruction: An application to remedial college algebra. Dissertation Abstracts International, 46, 2222A. (University Microfilm No. 85-23,769).

Wold, A. L., & Hunter, C. B. (1984). The not quite twenty-year history of educational software. Media and Methods, 37, 24-25.

Zinn, K. L. (1965). Computer assistance for instruction. Automated Education Letter, 1, 4-13.

APPENDIX
TABLES OF STUDIES

Table 1. Mathematics Studies

Author(s)	Sample Size	Duration of Study	CAI Software	Statistics
Rockhill (1971)	53	4 topics	self	T-tests
Schoen (1972)	60	Semester	self	ANOVA
Lang (1973)	34	Semester	self	ANOVA
Ozarowski (1973)	46	Semester	self	T-test, ANOVA
Goodson (1975)	93	1 topic	self	ANOVA
Sherman (1975)	117	Semester	self	ANOVAs
Shapiro (1977)	400	Semester	self	ANOVA
Sterrett & Karian (1978)	35	Semester	self	ANOVA
Pachter (1979)	29	1 topic	self	T-test
Crenshaw (1983)	43	Semester	CCC	T-tests
Shine (1983)	41	1 topic	self	ANCOVA
Walker & Azumi (1985)	153	5 months	MATH1-6 program	T-tests, regres.
Enochs & others (1986)	50	Semester	self	ANOVA, Pearson
Imboden (1986)	38	1 topic	self	ANOVA
Robichaud (1986)	32	Semester	self	T-tests
Wilson (1986)	38	6 topics	self	T-tests

mean sample size 79; standard deviation 92.3
mean sample size without Shapiro 57; standard deviation 35.8

Note. CCC is Computer Curricular Corporation System

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